

‘Thermodynamics of Architecture and Urban Fabric: Designing and Reshaping Cityscapes by Laws of Nature’

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‘Thermodynamics of Architecture and Urban Fabric: Designing and Reshaping Cityscapes by Laws of Nature’

Or better

The art of making a healthy city for healthy citizens

‘How human neurophysiology reacts to the organization and the forms of space, is the first step to produce undeniably sustainable new design for the 21st century.’

(Caperna; Tracada; Serafini, 2013)

Natural Laws of Form

**‘Urban fabric and emergent architecture following the rules of social historical indexes– hidden agenda in urban sprawl’
By Eleni Tracada**

Personal research since 1990s based upon field work in Florence and other Italian cities’ urban fabric led to:

Analysis of case studies of the phenomena encouraging ongoing and harmonious urban sprawl (concealed energetic lines of paths forming a hidden, unremitting agenda for future urban growth)

Natural Laws of Form



The presence of Fibonacci patterns is universal in nature, from galaxies to seashells, from magnetized droplets in a viscous medium to the organization of florets in plants (as shown in the figure for sunflowers). Moreover, the numbers of such spirals (clockwise versus counterclockwise) are typically Fibonacci numbers (21 and 34 respectively).

Natural Laws of Form



Natural forms are ruled by mathematics and physics. And also human beings are part of this natural world as well. Thus, by creating Biophilic designs today, we are not only able to intervene to both natural and built environment, but also to human bios (= active human lives)

New methods of designing or revitalising cities today follow new forms of Urbanism, such as Biourbanism:

- Biourbanism introduces new conceptual and planning models for a new kind of city, which values social and economical regeneration of the built environment through developing healthy communities.**
- Biourbanism combines technical aspects, such as zero-emission, energy efficiency, information technology, etc. and the promotion of social sustainability and human well being.**

- Biourbanism endorses principles of geometrical coherence, Biophilic design, Bio Architecture, Biomimesis, etc. in practices of design and also new urban policies to promote urban revitalization by ensuring that man-made changes do not have harmful effects to humans.
- Green city standards may originate inside the designs for each building and carry on affecting either unbuilt spaces surrounding buildings or even complex infrastructural networks and connections of buildings and people.
- New exciting developments recently, such as fractals, complexity theory, evolutionary biology and artificial intelligence are interrelated and constantly stimulate interaction between human beings and the surrounding built and natural environment.

Biourbanism considers the city as a living organism; it studies it within the frame of Integrated Systems Sciences and the last advancements of Life Sciences, such as:

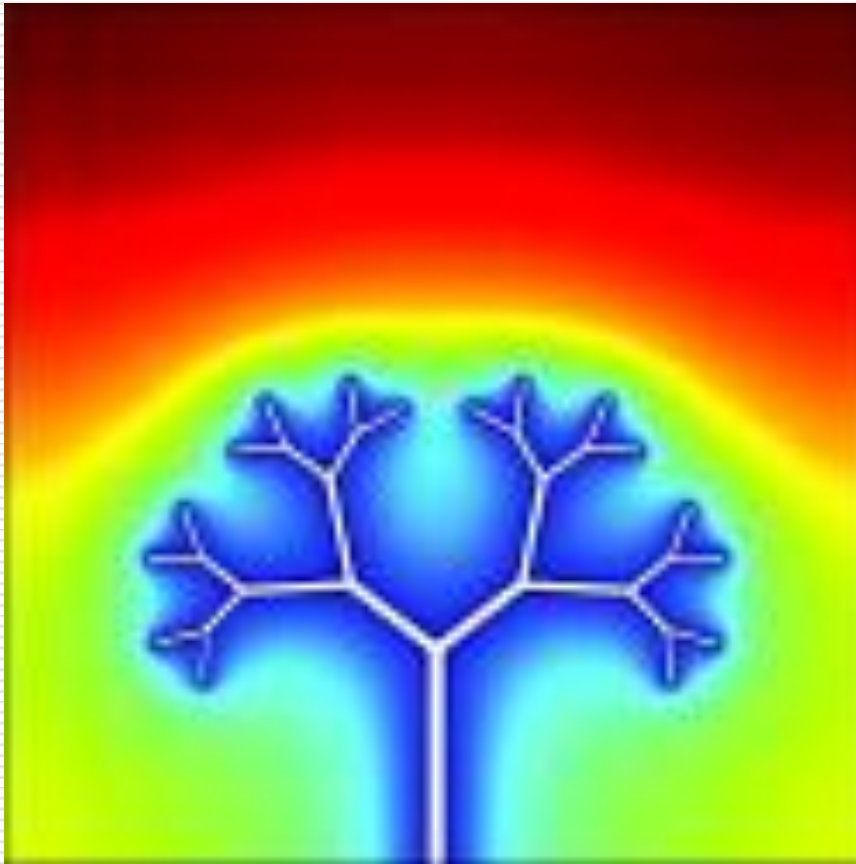
- Laws of form and Self-organization in evolution;
- Constructal Law;
- Morphogenetic processes

Constructal Law and Biourbanism

Constructal Law has been introduced by Adrian Bejan affirming that *'design is a universal phenomenon in nature. It is physics. It happens naturally when something is flowing and it is free to morph. Design unites the animate with the inanimate.'*

(Bejan & Lorente, 2013, p3).

Designs are **tree-shaped** (Bejan & Lorente, 2013)



**Tree-shaped
architectures:**
'Constructal invasion
of a conducting tree
into a conducting
body'
(Bejan & Lorente,
2013)

Constructal Law

‘Life is flow: all flow systems are live systems, the animate and the inanimate.’

(T. Basak, (2011) The law of life: the bridge between Physics and Biology. Phys Life Rev 8, 249-252)

‘Design generation and evolution is a phenomenon of physics.’

(L. Wang, (2011) Universality of design and its evolution. Phys Life Rev 8, 257-258)

“Biourbanism recognizes **optimal forms** defined at different scales (from the purely physiological up to the ecological levels) which, through **morphogenetic processes**, guarantee an optimum of systemic efficiency and for the quality of life of the inhabitants. A design that does not follow these laws produces anti-natural, hostile environments, which do not fit into an individual’s evolution, and thus fail to enhance life in any way.”
(www.biourbanism.org)

Some critical questions that designers should not avoid during design processes and practices may be:

- Why do some built forms resemble biological forms?
- What types of built forms correspond more closely to biological prototypes?
- Are human beings predisposed to like and feel comfortable with certain types of forms?
- Are human beings also predisposed to *build* certain types of forms?
- Is it worthwhile mimicking biological forms in what we build?
- Do we gain more than just aesthetic pleasure -- such as physical and psychological benefits, for example -- from an environment that captures the essence of biological structure?
- Can we damage ourselves by living in and around forms that contradict biological forms?
- Do we really understand biological structure well enough to mimic anything other than its superficial appearance?

Human sensory systems









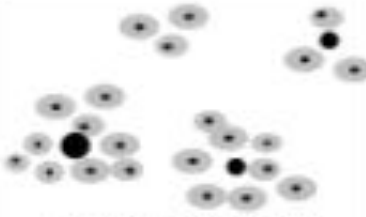
- Have evolved to respond to natural geometries of fractals, colors, scaling, symmetries
- Fine-tuned to detect pathologies of our body, signed by departure from natural geometries
- Human beings require contact with the geometry of biological structure
- Social and mental health deteriorates in nature-less surroundings

Historical and theoretical context in Design and Architecture - Patterns

**“Christopher Alexander (architect and urban designer) talks about patterns/codes and visual language and says that designers and architects should not only be able to write and read a language, but also be able to develop it further by understanding every feature of it and by giving it new meaning according to their own identity.”
(Tracada, 2006, p44)**

Biourbanism as Neuroergonomics in Design

Fractal coupling forces in mapping lines of communication between human beings and environments:

Strategic option	Local option		
	Free	Corridor	Cellular
Free	 <i>Super scatter</i>	 <i>Street matrix</i>	 <i>Cell soup</i>
Corridor	 <i>Super strip</i>	 <i>Axial lattice</i>	 <i>Cell strands</i>
Cellular	 <i>Super cells</i>	 <i>New urban townships</i>	 <i>Cellular clusters</i>

‘Traditional urban geometry is characterised by fractal interfaces’

(Batty & Longley, 1994; Bovill, 1996; Frankhauser, 1994; Salingaros, 2005)

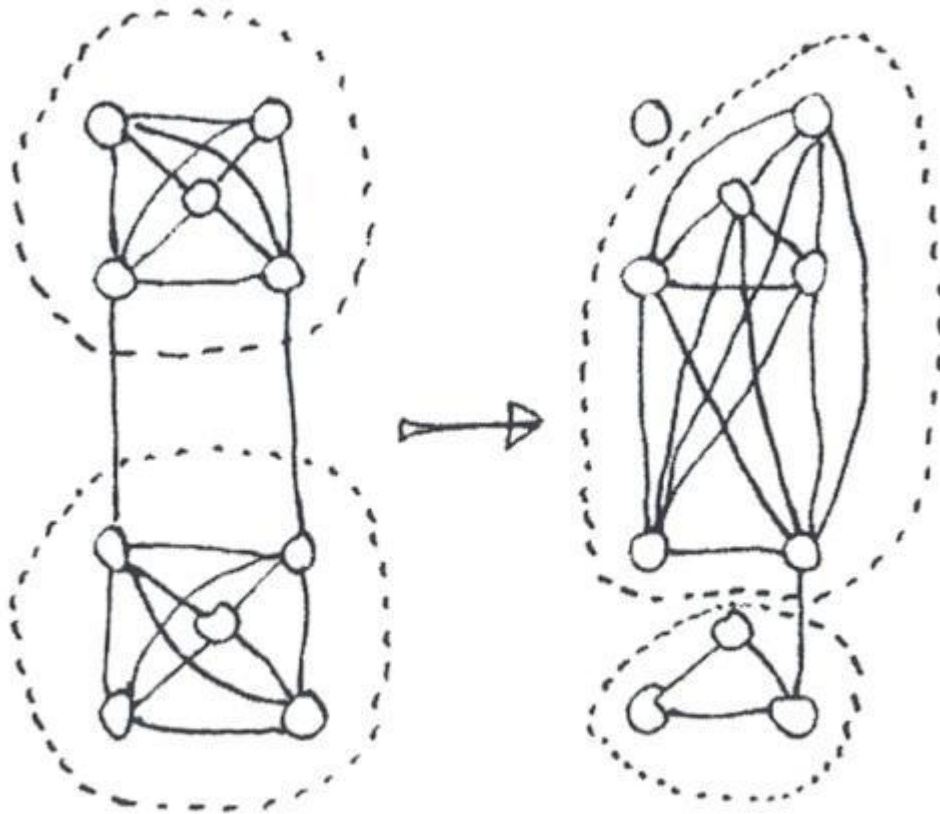


Fig. 8 Two modules reorganize themselves over time by defining new connections and new boundaries.

Cities evolve their own *organic/fractal form* by self defining it through connectivity of people on the move in cities.

(Salingaros, 2008)

The aforementioned theories and practices have been discussed with students since 2010-2011 in the *Designing Environments* module (MSc Sustainable Architecture and Healthy Buildings) and in *Urban Design and Research* undergraduate final year module. Hence, interesting theoretical and applied projects have been produced since then.

‘The focal elements or nodes at this scale could not be understood without the smallest scales to give coherence to the whole. Some nodes establish links with the smaller scales through functionality as the main purpose for interaction (markets, schools, churches, workplace, etc.) and other nodes mainly through visual and structural coherence (parks, squares, etc.), although a combination of all these factors is more likely to occur in any case. The strongest connections are the small scale, local ones.’

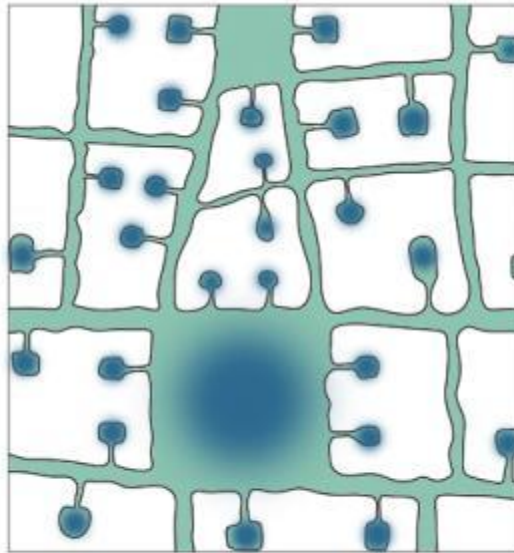


Fig. 4 Self-similar interactive social nodes at the community and urban scales.



Fig. 5 Island of El Trocadero, Puerto Real, Cádiz. (<http://fractaldonana.blogspot.co.uk/>)

Student paper for Designing Environments, 2012

Fractal cities: symmetries and patterns of fabric influencing human well-being

**‘Plans, patterns, symmetry, axes, are only of secondary importance relative to the fundamental processes that generate urban space. This lends support for the irregularity of successful urban spaces.’
(Salingaros, 1999)**

Emergence and **Morphogenesis** in architecture **Nature** re-proposed by Computation and **Maths**

**‘The movement from low-level rules to higher-level sophistication is what we call emergence’; and ‘... a higher-level pattern arising out of parallel complex interactions between local agents.’
(Steven Johnson, Emergence, the Connected Lives of Ants, Brains, Cities and Software, Penguin Press, 2001)**

Steven Johnson identifies as four principles of emergence: local interaction of neighbours, pattern recognition, feedback and indirect control.

Emergence and **Morphogenesis** in architecture **Nature** re-proposed by Computation and **Maths**

‘Emergence is a classical concept in systems theory, where it denotes the principle that the global properties defining higher order systems or ‘wholes’ (e.g.. Boundaries, organisation, control ...) can in general not to be reduced to the properties of the lower order subsystems or ‘parts’. Such irreducible properties are called emergent.’

‘The spontaneous creation of an ‘organised whole’ out of a ‘disordered’ collection of interacting parts, as witnessed in self-organising systems in physics, chemistry, biology, sociology ... is a basic part of dynamical emergence.’

(Francis Heylighen, ‘Self-Organisation, Emergence and the Architecture of Complexity, in Proceedings of the 1st European Conference on System Science, Paris)

Emergence and **Morphogenesis** in architecture **Nature** re-proposed by **Computation and Maths**

‘We are everywhere confronted with emergence in complex adaptive systems – ant colonies, networks of neurons, the immune system, the internet, and the global economy, to name few – where the behaviour of the whole is much more complex than the behaviour of the parts.’

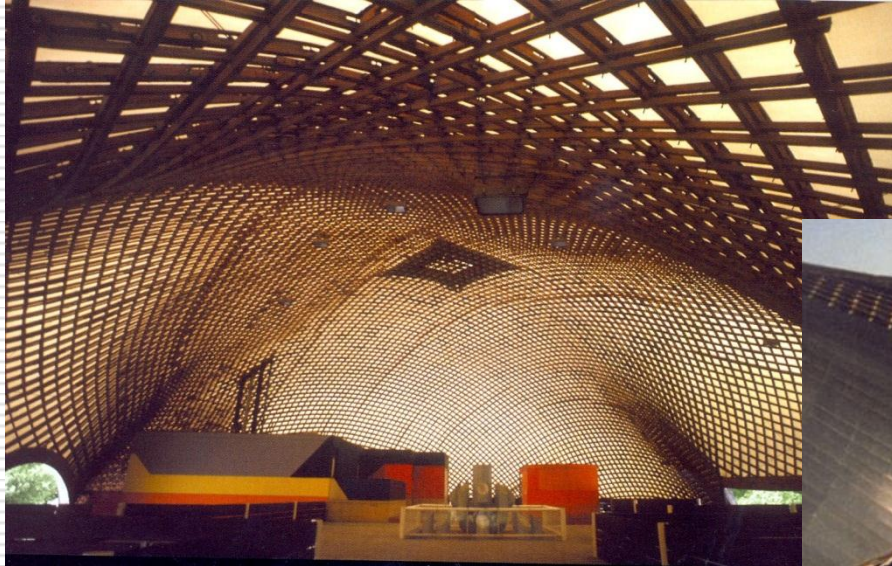
‘... it is unlikely that a topic as complicated as emergence will submit meekly to a concise definition, and I have no such definition to offer. I can, however provide some markers that stake out the territory, along with some requirements for studying the terrain...’

John Holland in Emergence from Chaos to Order, Oxford University Press, 1998.

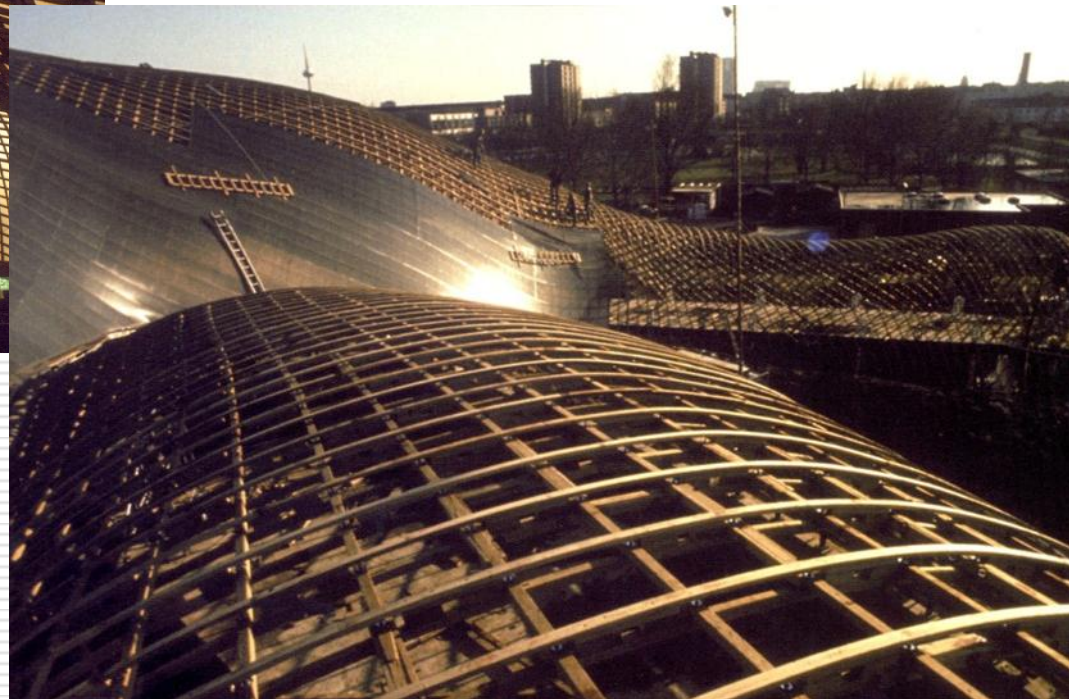
Emergence and **Morphogenesis** in architecture **Nature** re-proposed by Computation and **Maths**

**‘Process rather than substance was the fundamental constituent of the world. Nature consists of patterns of activity interacting with each other. Organisms are bundles of relationships that maintain themselves by adjusting their own behaviour in anticipation of changes to the patterns of activity around them.’
(Alfred North Whitehead, mathematician and philosopher in The Concept of Nature, Cambridge University Press, 1920)**

Emergence and **Morphogenesis** in architecture **Nature** re-proposed by Computation and **Maths**

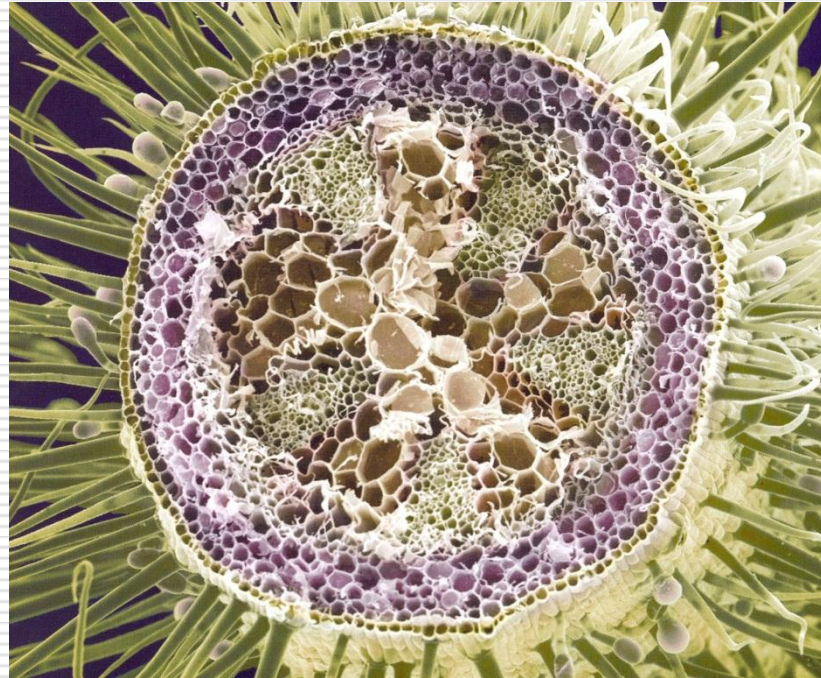
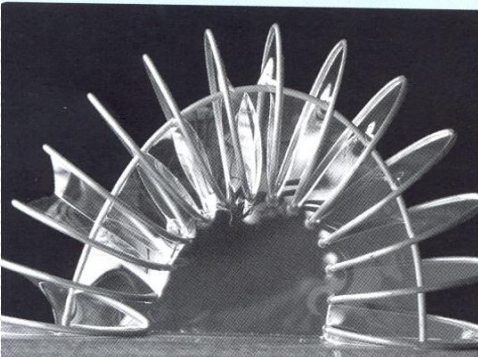
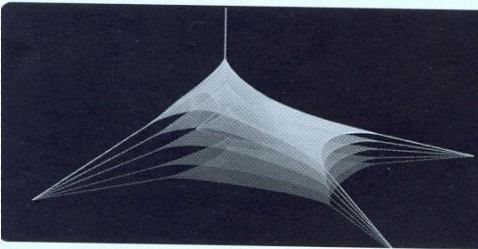
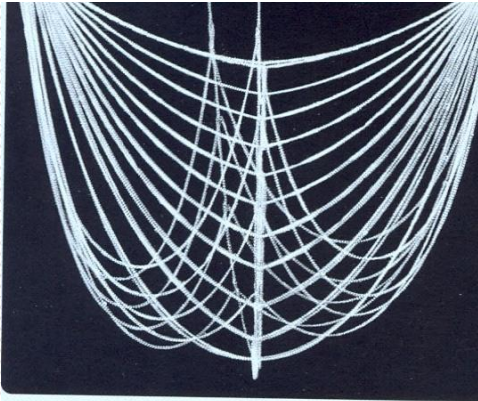


**Frei Otto, Multihalle
Manheim, Germany, 1975**



Emergence and Morphogenesis in architecture

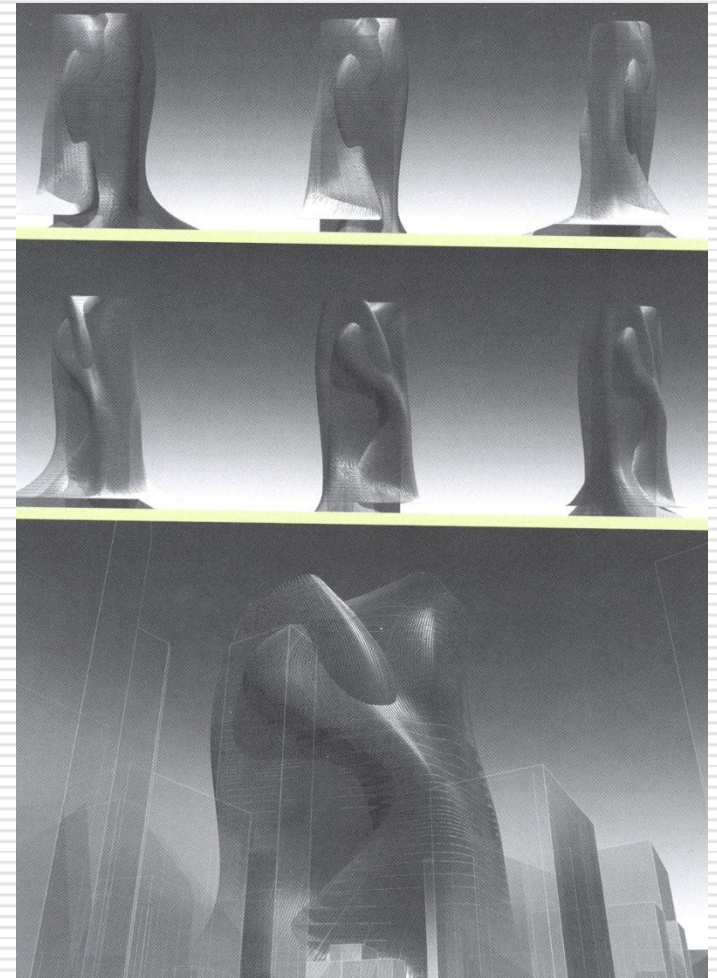
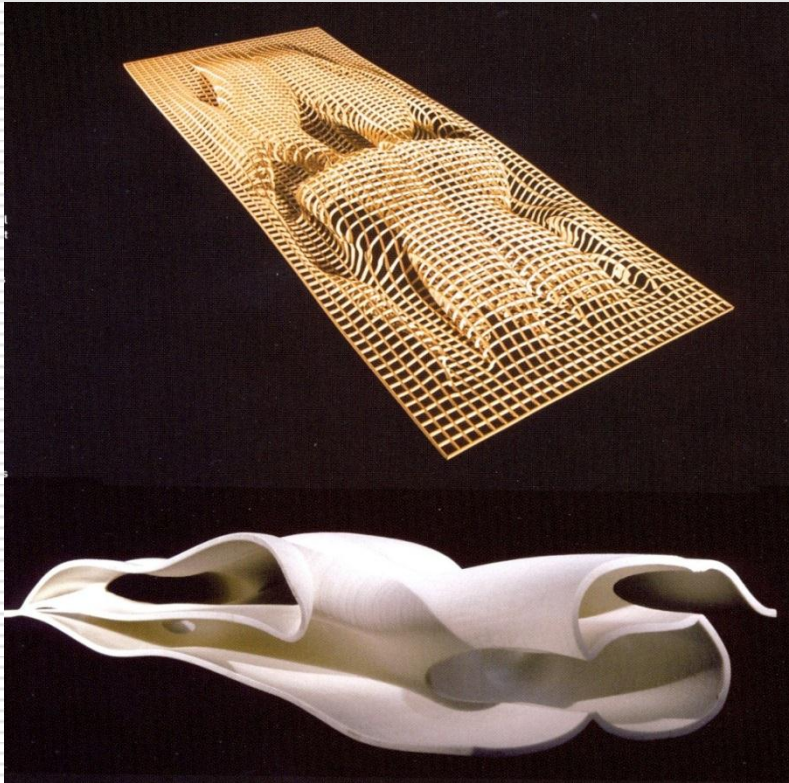
Nature re-proposed by Computation and Maths



**Frei Otto,
Maeda Workshop, 2003**

Emergence and Morphogenesis in architecture Nature re-proposed by Computation and Maths

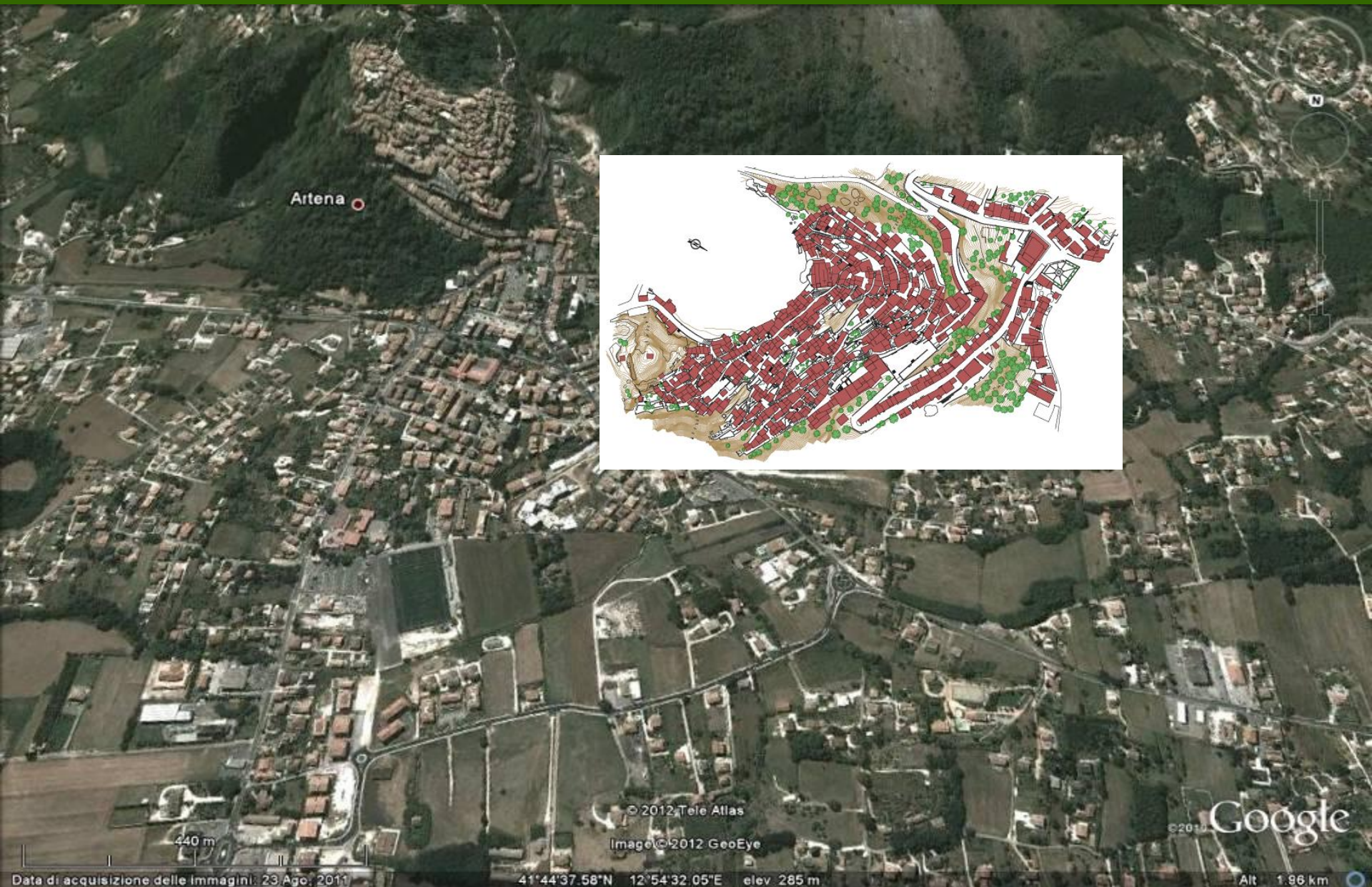
Finding Exotic Form: An Evolution of Form Finding as a Design Method



Theories and practices of Biourbanism and laws of nature were taught and applied in student work during the *Progetto Artena* and the latest Summer schools in July 2012 and July 2013 which were organised by the International Society of Biourbanism in Artena, Province of Rome, Italy.

Progetto **A**rtena

SMART **C**ommunity



**Tracada E. 'Thermodynamics of Architecture and Urban Fabric::
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Smart Community- Artena

- Social capital
- Economical capital
- Cultural growth
- Town and country planning according to Biourbanism approach

Artena Village, Province of Rome, Italy



Artena Village, Province of Rome, Italy

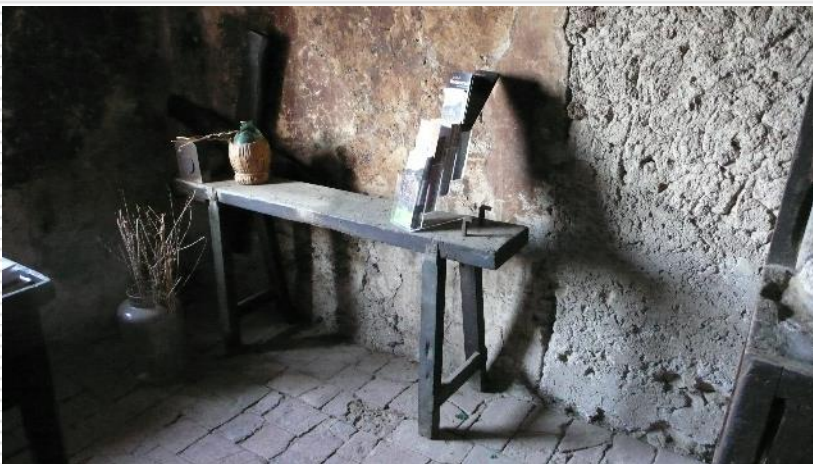


Artena Village, Province of Rome, Italy



Artena Village, Province of Rome, Italy

Collaborative projects in '*Ruin Academy*'



Artena Village, Province of Rome, Italy 'Ruin Academy' founded by Marco Casagrande



Artena Village, Province of Rome, Italy

'War Memorial Garden', 2013 –

inside a site bombed during World War II



Thermodynamics and Urban Fabric

Wellbeing of city inhabitants, according to Nikos Salingaros' theoretical and mathematical considerations in Thermodynamics

Architectural Temperature = **T**

Architectural Harmony = **H**

Architectural Life = **L**

Architectural Complexity = **C**

Architectural Life = **Temperature** times **Harmony**

L = **TH**

Architectural Complexity = **Temperature** times **Disorder**

C = **T (10-H)** = **Randomness**

Thus, random and complex fractality boundaries of cities define new expansions and urban healthy fabric.

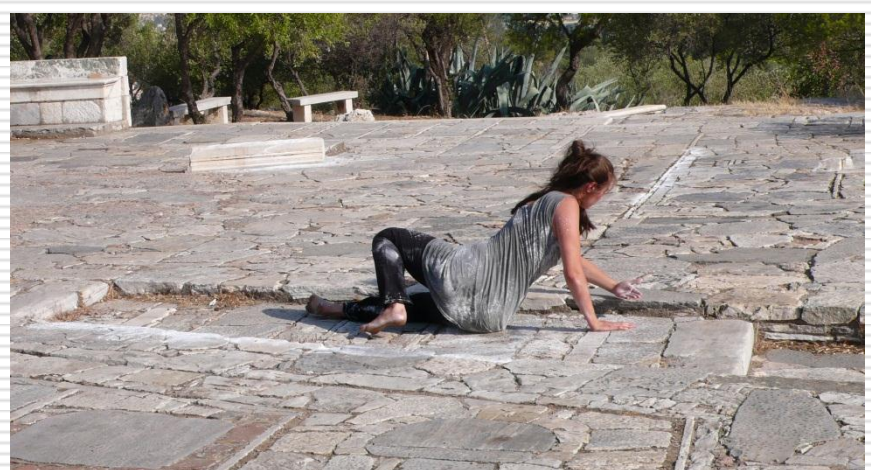
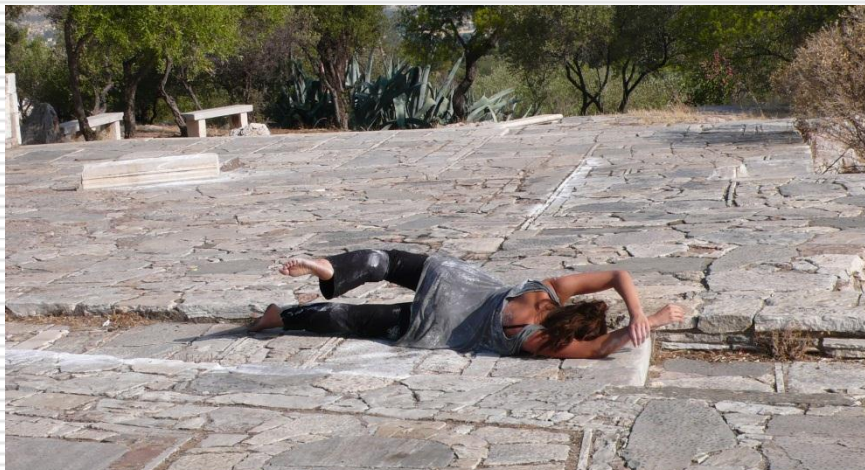
Urban science and theories of human behaviours inside built and non-built environments

The human mind establishes a deep connection with the environment by possessing geometrical information from its surroundings

People recognise what looks and feels natural by its scaling hierarchy and also react accordingly

The mathematical qualities of meaningful environments are those that manifest themselves in fractal subdivisions (an inverse-power distribution of sizes)

Architectural Spatiality Explored by Human Bodies in Free Motion



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**Many thanks for your
attention**

Any questions?